Television Theory Of Operation

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My TV Background

• 34 years in Automation and Image Electronics
• MS in Electrical and Computer Engineering
• Designed Television Equipment
• On an Engineering Team Awarded
  – 2 Emmy Awards for Outstanding Television Engineering
• Designed Helicopter Television and IR Cameras
• Designed Digital Projectors for InFocus (this one too!)
• Designed Flat-panel HDTV IC’s (Home Theater)
  – Sony, Sharp, Samsung, LG, HP, Dell, all were customers
TV Theory of Operation

1. **CRT** Picture Tube Basic Operation,
2. **Comparison** to LCD and Plasma Flat Screen TV
3. **RF** De-Modulation and Channel Selection
4. Composite **Video Baseband Signal** (CVBS)
5. **(Y/C)** Luminance/Chrominance Separation
6. **Phase-Lock Loop (PLL)** of Color Subcarrier Oscillator
7. **SC (Subcarrier)** Demodulator/Mixer and **LPF**
8. **Color Space Conversion (CSC)** to R/G/B intensities
9. **Horizontal and Vertical Scan Timing** (H-lock/V-lock)
10. **Beam** Control in CRT and **Raster** Control in LCD
Black-and-White TV Block Diagram
Tri-color Theory of Color TV

1. Red, Green, and Blue can make almost any color
2. Color CRT’s use red, green, and blue beams
3. Color CRT’s use “additive” color
4. The **intensity** of each beam determines color
5. **Equal** intensities on R/G/B make white or gray
6. Equal Red and Blue make Violet, for instance
Color TV Block Diagram

RF Demodulator Module

Luminance Processing

Chroma Mixer/Demodulator

Color Subcarrier Oscillator

Color Space Converter

Audio

H-Locked and V-Locked Beam Scan Oscillators

Power Supplies

REQUIRED FOR CRT's
Newer TV: Digital Signal Processing
A Tuner Module and a DSP Computer “Chip” Do Everything, Except For CRT Beam Control or LCD Raster Control
TV Picture Tube Operation

3 Electron Beams Strike Red/Green/Blue Pixel Cluster (A)
Magnify Screen: You Can See Red/Green/Blue Phosphor Dots

A Cathode  B Conductive coating  C Anode
D Phosphor-coated screen  E Electron beams  F Shadow mask
TV Picture Tube Operation

(These unfortunate color choices have nothing to do with R/G/B beams; they apply to each of the red, green, and blue beams)

**Electron Beams** “Paint” the RGB Image on Tri-color Phosphors, Left-to-Right. Beam is **Off** During Dotted-Red **Horizontal Re-Trace** Back to Scan Next Line. Beam is **Off** again during green **Vertical Re-Trace** to Top
TV Picture Tube Top View

- > 25kV
- H.V. Supply
- Focus Coils
- Anode
- Cathode
CRT Cathode/Anode/Coils
Focus Coils Tune Convergence (Alignment) of the 3 RGB Beams
# TV Main Components

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<th>New Flat Panel TV</th>
<th>Old CRT TV</th>
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<td>• LCD or Plasma Display</td>
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<td>• Analog-to-digital converters</td>
<td>• Hsync and Vsync processors</td>
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<td>• Y/C (luma/chroma) Separator</td>
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<td>• ACC (Auto Color Control)</td>
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<td>• Color Space Converter</td>
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<td>• H/V CRT drive amplifiers</td>
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## TV Comparison

### New Flat Panel TV
- Has digital capability
- Few parts (impossible to fix)
- Computerized inside (SW)
- Many software adjustments
- Programs can “crash”
- Very long life
- 1<sup>st</sup> Repair: needs adjustment
- 2<sup>nd</sup> Repair: bad connections

### Old CRT TV
- No digital capability
- Many parts (hard to get)
- Special Integrated Ckts
- Few analog adjustments
- Parts can “age” over time
- Life limited by picture tube
- 1<sup>st</sup> Repair: needs adjustment
- 2<sup>nd</sup> Repair: bad connections
Television Tuner Module

“Baseband” Video Signal
Composite Video Baseband Signal (CVBS) Output From Tuner in Time Domain

Oscillogram of composite PAL signal - two lines.
“Baseband” Video in Frequency Domain
(Audio is Different Output from Tuner; Not Part of CVBS Output)

Frequency Spectrum per transmitted channel

spectrum of a system G (bands IV and V) television channel with PAL colour.)
CVBS “Baseband” Video Frequencies

1. Simple frequency-selective filters can separate Color from B&W
   - LPF = Low Pass Filters
   - BPF = Band Pass Filter
   - HPF = High Pass Filter
   - NotchF = Notch Filter

2. There is a problem because Chroma overlaps Luminance (B&W)

3. Color can be wrongly detected as B&W detail, called “dot crawl”

4. B&W Luminance can be wrongly detected as “cross-color”

5. All simple pass-band filters have this problem

6. Special “Comb” Filters can minimize this problem
   - Use Color Subcarrier “phase-flipping” each line to cancel color
“Multiburst” CVBS Test Signal is Helpful to Identify Filter Effects for Selected Frequencies

FIGURE 4B. IDEAL MULTIBURST WAVEFORM FROM VIDEO GENERATOR
**HPF and LPF** to Separate Color (Chrominance) and Black-and-White (Luminance)

**FIGURE 3. LOW PASS FILTER TECHNIQUE SPECTRUM**
Multiburst Test Signal After LPF, Showing Elimination of High Frequencies

FIGURE 5B. MULTIBURST WAVEFORM FROM HIGH PASS/LOW PASS
BPF and NotchF to Separate Color (Chrominance) and Black-and-White (Luminance)

FIGURE 6. TRAP FILTER SEPARATION TECHNIQUE
**NotchF Effect** is to Eliminate **Chroma** Frequencies Showed as Missing Frequency “Burst” at 4.4MHz

*FIGURE 9B. MULTIBURST WAVEFORM FROM TRAP FILTER*
Luminance Texture Can Still Pass Through the Chroma BPF (or HPF) and Becomes “Cross-Color” Artifact (often seen on jackets & ties)
Color Edges Can Sometimes Get Decoded as Black-and-White
Detail -- Displayed as dots, or “Dot Crawl”
**PAL Comb Filter** Separates Color From Luminance (B&W) With Best Detail and Least Cross-color

**FIGURE 8A. PAL LINE COMB FILTER TECHNIQUE**

**FIGURE 8B. COMPOSITE PAL INTERLEAVE SCHEME**

**FIGURE 8C. Y COMB FILTER RESPONSE**

**FIGURE 8D. C COMB FILTER RESPONSE**
Luminance Resolution Chart = Picture Detail
Higher Bandwidth (Frequency Response) Means More Detail

Figure 4. Representative visual resolution test pattern.
Higher Frequency Bandwidth Means **More Detail**

**Figure 4.** Representative visual resolution test pattern.

High-Definition TV  
(ATSC or DVB-T)

Standard-Definition TV  
(PAL Broadcast TV)

DVD Video
PAL Colour Bar “Chroma Envelopes”

Sinewave Amplitude is “Saturation” (low = pale; high = vivid)
Phase Difference from Color Burst Reference is “Hue” (Blue, Red, etc)

Figure 6. Composite video waveform: color bars.
Detail of **Color Burst** Signal on CVBS

Used as **Hue phase** reference and **auto-color** reference
PAL Colour Bar “Chroma Envelopes”

Shaded areas are 4.418MHz Color Subcarrier Sinewave.

Sinewave Phase is “Hue”, Sinewave Amplitude is “Saturation”
PAL Colour Bars on Oscilloscope

Figure 1. A waveform monitor display of colour bars.
“Chroma” **C** After **Y/C** Separation  
(Only Color Subcarrier Remains; **Y** is Gone)
Conversion to Red/Green/Blue

• Color displays require Red, Green, and Blue (RGB) drive signals
• First separate Chroma Subcarrier from Luminance (Y/C Sep)
• Lock “subcarrier oscillator” to the reference color burst
  – Use a crystal “Phase-Locked Loop” (PLL)
• SC oscillator generates “Quadrature” components sin/cos
  – Mix (multiply) Chroma with Sine and Cosine oscillator outputs
  – Low-pass filter the 2 chroma mixer outputs (to remove harmonics)
  – Result is two “color difference” signals (R-Y) and (B-Y)
  – Apply Color Space Conversion matrix to Y, R-Y, B-Y (Y, Pr, Pb component)
  – Result is R, G, and B to drive three-color display.
• Now Get the Scan Timing Right!
Color Decoding Block Diagram

CVBS >> Y/C >> Y/(B-Y)/(R-Y) >> R/G/B
Chroma Demodulator Detail Block Diagram

- **Luminance Processing**
  - 1st VIDEO AMPLIFIER
  - DELAY LINE
  - 2nd VIDEO AMPLIFIER
  - Y

- **Chroma Mixer/Demodulator**
  - CHROMA AMPLIFIER
  - BANDPASS AMPLIFIER
  - R-Y DEMODULATOR
  - MATRX AMP
  - G-Y

- **Color Subcarrier Oscillator**
  - Phase-Locked Loop to Burst Phase
  - B-Y AMPLIFIER
  - G-Y AMPLIFIER
  - R-Y AMPLIFIER
  - MATRIX
PAL Colour Bars on TV “Vectorscope”

Polar Coordinates: Angle shows Phase (Hue)
Radial Distance is Saturation

Figure 2. A vectorscope display of colour bars.
Y/(B-Y)/(R-Y) to R/G/B Color Space Converter
Decoding and Color Space Conversion

CVBS $\rightarrow\rightarrow\rightarrow$ Y/Pr/Pb $\rightarrow\rightarrow\rightarrow$ R/G/B

"Composite" Video  "Component" Video  "RGB" Video
Horizontal & Vertical Drive Oscillators

“Locking” Horizontal and Vertical Beam Sweep Generators
Vsync and Hsync Timing for Electron Beam Scan of Phosphors
Detail of **HSync** Signal on CVBS

Starts **Horizontal** Synchronization of Each Scan Line

Line Synchronizing Signal

Specifications differ by Television System (PAL or NTSC)
**Field Vsync** Starts “Top of Picture”

*Vertical* Synchronization Occurs at the Top of the Picture after the Electron Beam has “Painted” a Full Screen. Also called “Vertical Retrace” (CRT beam is off)

Details of B,G/PAL field synchronizing signals
Horizontal & Vertical Drive Oscillators

H/V Oscillator Sweep Timing is Now “Locked” to Incoming CVBS

H-Locked And V-Locked Beam Scan Oscillators
CRT Geometric Distortion Adjustments

5-4. PICTURE DISTORTION ADJUSTMENT

Item Number 00 – 08

00 HSF (H SHIFT)

Horiz. Position

01 HSZ (H SIZE)

Horiz. Width

02 PAP (PIN AMPLITUDE)

“Barrel”

03 CNP (CORNER PIN)

“Pincushion”

04 TLT (TILT)

“Tilt”

05 VSL (V SLOPE)

Vertical Height

06 VAP (V AMPLITUDE)

07 SCR (S CORRECTION)

08 VSF (V SHIFT)

Vertical Position

Note) 01 HSZ, 02 PAP, 03 CNP and 04 TLT are not adjustable for this model.
Matrix or “Raster” Displays

1. LCD or Plasma
2. Both have fixed “native” pixel-resolution, such as 1024x768
3. Both display many resolutions, but work best at native
4. Both are better for digital video than CRT
5. Both have built-in scan driver I.C.’s
6. NO geometric distortions like CRT (unless rear-projection)
7. LCD uses low-voltage only, Plasma has high voltage
8. LCD pixels are always on, unlike CRT phosphor scan
9. Plasma and LCD are much brighter than CRT
10. LCD has better color and longer life than CRT (or Plasma)
High LCD/Plasma Pixel-Resolution Means **More Detail**

High-Definition TV (LCD or Plasma, at 1024x768 pixels)

Standard Picture Tube Broadcast (PAL) TV

CRT Best Resolution
Digital TV Decoding - Block Diagram

RF >> MPEG >> Y/C<sub>R</sub>/C<sub>B</sub> (4:2:0) >> R/G/B digital

PAL Countries Use DVB-T for HDTV
NTSC Countries Use ATSC for HDTV

RF

DVB-T Tuner Demodulator

Digital MPEG Stream

Right Digital Audio
Left Digital Audio

Y (8-bit digital)
C<sub>R</sub> = R-Y (8-bit digital)
C<sub>B</sub> = B-Y (8-bit digital)

Pixel Resolution Converter and Color Space Converter and Gamma Correction

Red (10-bit)
Green (10-bit)
Blue (10-bit)

LCD or Plasma Digital Panel Driver Interface

“Component” 4:2:0 Digital Video
Digital “RGB” at Panel Pixel Rate